21.0 Producers of Colored Glass

21.1 Industry Profile

This industry includes companies that produce colored glass. The applicable Standard Industrial Classification (SIC) code for this industry is 32, Stone, Clay, and Glass Products. SIC Code 3229, Pressed and Blown Glass, n.e.c, is a more applicable classification. The applicable North American Industry Classification System (NAICS) code for this industry category is 3272, Glass & Glass Product Mfg. This category includes such subcategories as flat glass manufacturing (NAICS Code 327211), other pressed and blown glass and glassware manufacturing (NAICS Code 327212), glass container manufacturing (NAICS Code 327213), and manufacturing of glass products made of purchased glass (NAICS Code 327215). As discussed below, it is believed that the majority of chromium used today in colored glass is included in NAICS Code 327212, Other Pressed and Blown Glass and Glassware Manufacturing. Data on the number of establishments, employees, and firms for this NAICS code are presented in Table 21-1.

Table 21-1. NAICS Code 327212 (Other Pressed and Blown Glass and Glassware Manufacturing) Employment Data

Employment Size by Establishment	Establishments[a]	Employees	Firms[b]
Total	529	37,007[a]	484
1 - 19	405	1,811[c]	405[d]
20 - 499	103	13,033[c]	50
500+	21	22,163[c]	29

[a] 2000 County Business Patterns.
[b] 1999 Statistics of U.S. Businesses (Firms are classified according to enterprise size, not establishment size).
[c] Employees are allocated to size classes based on the percentages of employees in these size classes reported in the 1997 U. S. Economic Census, since some data by size class are unavailable in County Business Patterns to preserve confidentiality.
[d] Number of firms adjusted so as not to exceed the number of establishments, assumes industry consolidation from 1999 to 2000.

It is believed that art glass production represents the majority of hexavalent chromium–containing pigment use within this industry (GPI, 2002). Art glass falls under the seven-digit NAICS Codes 3272123 (Machine-made pressed and blown table, kitchen, art, and novelty

glassware, made by establishments producing glass) and 3272129 (Handmade pressed and blown glassware, made by establishments producing glass), which further define the industry sector expected to be exposed to hexavalent chromium. Data on the estimated number of establishments and employees for these seven-digit NAICS codes are only available from the 1997 U.S. Economic Census. Table 21-2 applies the percentage of establishments and employees reported for NAICS codes 3272123 and 3272129 in the 1997 Economic Census to the data presented in Table 21-1.

Table 21-2. NAICS Codes 3272123 (Machine-made pressed and blown table, kitchen, art, and novelty glassware, made by establishments producing glass) and 3272129 (Handmade pressed and blown glassware, made by establishments producing glass) Employment Data[a]

Employment Size by Establishment	Establishments	Employees	Firms[b]
Total	58	11,287	53
1 - 19	44	552	44
20 - 499	12	3,975	6
500+	2	6,760	3

[a] Table 21-1 adjusted by the distribution of establishments and employees in NAICS Codes 3272123 and 3272129 in the 1997 U.S. Economic Census because data for these NAICS codes are not presented in either the 2000 County Business Patterns or the 1999 Statistics of U.S. Businesses.
[b] Firms are classified according to enterprise size, not establishment size.

Chromium is frequently used in the production of colored glass, particularly colored art glass. Chromium is found in green and red-orange pigments, as trivalent chromium in chromium oxide (green pigments), and as hexavalent chromium in potassium dichromate (red-orange, blue, green, and blue-green pigments). Chromium green is a staple ingredient for this industry. Several product specifications require its use (NIOSH, 2002).

In producing glass product containers, color is imparted to glass to protect the contents from ultraviolet radiation (Centaur, 1981). A representative of the Glass Packaging Institute (GPI) stated that trivalent chromic oxide is used as a colorant in the manufacture of green-colored wine and beer bottles. While hexavalent chromium, in the form of chromic acid, was occasionally added in the past to green-colored glass as a yellow coloring agent, it has not been used for over 15 years. No hexavalent chromium pigments are used today in the glass container industry (GPI, 2002). Kirk-Othmer and Roskill (1993) report that chromium oxides may be used to impart a

black color to glass. For all of these colors of glass, substitute colorants are available (Kirk-Othmer, 1994). For example, V_2O_3, CdS, and Co_3O_4 can be used to impart green, yellow, and black colors to glass, respectively.

It is believed that the majority of hexavalent chromium used in the colored glass manufacturing industry is used in producing art glass, NAICS Codes 3272123 and 3272129. According to the NIOSH site visit report, there are approximately six large establishments that manufacture art glass (NIOSH, 2002). Estimating 24 percent of all establishments to be large and 76 percent to be small establishments (2000 County Business Patterns; 1997 U.S. Economic Census), there are 19 small establishments that manufacture art glass. Based on data from the NIOSH site visit report (NIOSH, 2002), the six large establishments are estimated to employ approximately 180 people, who may be potentially exposed to hexavalent chromium. It is estimated that an additional 114 employees working for small firms are exposed to hexavalent chromium, projecting an average of six exposed employees per small establishment.

21.2 Process Description

The following process description is based on a site visit conducted by NIOSH to a large colored art glass manufacturer (NIOSH, 2002). This company is the largest manufacturer of handmade, pressed and blown glass in the U.S. Several smaller companies also manufacture colored glassware. The company produces a diverse collection of art glass products, highly sought after by customers who collect this type of handmade glass art. Approximately 30 of the production employees are exposed to hexavalent chromium at this facility. On an average, 2.5 batches of hexavalent chromium-containing glassware are produced per week at this facility.

There are three job categories that are potentially exposed to hexavalent chromium in this industry: lab assistant, batch mixer, and furnace worker. In addition to quality assurance (QA) laboratory responsibilities, the lab assistant weighs pigments for the colored glass. Pigments are dispensed from a plastic drum into a plastic bucket using a metal scoop. The pigments are then delivered to the batch mixers. The time spent working with hexavalent chromium is approximately 1 minute per batch. Personal protective equipment includes steel-toed boots, safety glasses, disposable gloves, and half-face negative-pressure respirators.

Batch weighers assist the lab assistant in weighing out pigments and other ingredients (cullet, soda ash, feldspar, etc.) for the colored glass. Large quantities of materials are added to a hopper through a valve using gravity-feed. Smaller quantities of material (including the pigments) are

added to the hopper through the use of shovels, scoops, buckets, forklifts, wheelbarrows, and other automated and manual equipment. A typical batch of colored glass contained three pounds of pigments. Once all the ingredients are added to the hopper, the hopper is lifted above the mixer with a crane, and the dry ingredients are added to the mixer. Approximately 12 batches are mixed per mixer per day. Pigment addition takes less than 1 minute per batch. After the batch is mixed, the batch mixers collect the mixed ingredients from the bottom of the mixer in another hopper and take them to the furnace workers. Batch mixers also clean the mixers, hoppers, mixer canopy, and dust-collector bags, as necessary. Personal protective equipment includes steel-toed boots, safety glasses, cotton or leather gloves, and half-face negative-pressure respirators.

A hopper of ingredients is brought from the mixer to the furnace with a forklift and lifted over the screw-charger feed chute. The furnace workers open a gate on the bottom of the hopper to allow the ingredients to fall onto the screw-charger feed chute. The screw-charger then feeds the ingredients into the furnace. The furnaces operate 24 hours per day, 365 days per year. Spilled ingredients are cleaned up with a broom and dustpan. The furnace workers also empty the waste glass containers, move hoppers and equipment, and adjust the temperature and monitor furnace operation. Personal protective equipment includes steel-toed boots, safety glasses, leather gloves, and half-face negative-pressure respirators.

Molten glass is removed from the furnace tanks by glass blowers, or gaffers, using puntils, metal rods on which the molten glass is handled. Hexavalent chromium is converted to trivalent chromium in the furnaces (NIOSH, 2002); therefore, the finished glass products are not expected to contain any hexavalent chromium.

The estimated total number of workers exposed to hexavalent chromium in each job category is presented in Table 21-3. The estimates for large establishments are based on information from the NIOSH site visit to a colored-glassware manufacturing plant (NIOSH, 2002). It was projected that each of the 19 small establishments producing colored-glassware employs one batch mixer and five furnace workers.

Table 21-3. Number of Employees Exposed to Hexavalent Chromium by Job Category in the Colored Glass Industry

Job Category	Number of Employees in Large Facilities[a]	Number of Employees in Small Facilities[b]	Total Number of Employees
Lab Assistant	6	0	6
Batch Mixer	24	19	43
Furnace Worker	150	95	245
Total	180	114	294

a Estimate of number of employees in large facilities is derived from information in NIOSH Site Visit (NIOSH, 2002).

b Number of employees per job category in small facilities is based on a model small facility whose average employment exposed to hexavalent chromium is six workers per facility. Based on 19 affected facilities in this industry,it is projected that batch mixers also perform lab assistant functions at small establishments.

21.3 Exposure Profile

Workers in three job categories are potentially exposed to hexavalent chromium: lab assistant, batch mixer, furnace worker, and technician. Exposure data for this industry are available from data obtained at a colored-glassware manufacturer during a site visit conducted by the National Institute for Occupational Safety and Health (NIOSH, 2002) and from the Occupational Safety and Health Administration (OSHA) Integrated Management Information System (IMIS) database.

Full-shift hexavalent chromium exposure data collected in 1999 at a colored-glassware production plant visited by NIOSH documented worker exposures to hexavalent chromium (NIOSH, 2002). The exposure data associated with this site visit are shown in Table 21-4. Nine personal full-shift personal breathing zone samples were collected during the survey. Air samples were collected using Gillian® Model 17G9 Gil-Air sampling pumps at a flow rate of 2 liters per minute. Sampling media (filters) were analyzed by OSHA Method ID-215. Personal exposure samples were collected on lab assistants, batch weighers, and a furnace worker. Only one of the nine personal 8-hour TWA samples detected any hexavalent chromium (0.02 $\mu g/m^3$); the remaining samples did not detect any hexavalent chromium.

Table 21-4. Hexavalent Chromium Monitoring Data Collected at a Colored-Glassware Production Facility During a Site Visit (NIOSH, 2002)

Type of Sample	Job Category	Hexavalent Chromium Exposure ($\mu g/m^3$)[a]
Full-shift TWA[b]	Lab assistant	<0.02
		0.02
Full-shift TWA	Batch mixer	<0.02
		<0.02
		<0.02
		<0.02
		<0.02
		<0.02
Full-shift TWA	Furnace worker	<0.02
Short-term	Furnace worker	<0.08
Area (full-shift)	Mixing room	<0.02
Area (full-shift)	Mixing room	<0.02
Area (118 min)	Furnace area	<0.05

[a]$\mu g/m^3$ = Micrograms per cubic meter.
[b]TWA = Time-weighted average.

In a 1990 Health Hazard Evaluation (HHE) study (NIOSH, 1990), NIOSH collected personal and area total chromium exposure samples at Thomson Consumer Electronics, a television picture tube manufacturer. The source of chromium was not specified; most likely, it was from raw material impurities, welding fumes, and/or refractory ovens. It was not necessarily from the making of the tubes themselves. Chromium was detected in two of five personal breathing samples and one of two area samples. It should be noted that sampling was performed for total chromium, and not hexavalent chromium. Because the data are for total chromium (not hexavalent chromium) and because the source of chromium in the exposure is unknown, these data are not included in the overall exposure profile. Table 21-5 presents the personal and area monitoring data for total chromium collected at this plant. Inspector/packers inspect the glass tubes as they exit the furnace. Code daters etch the glass after it has cooled.

A review of the OSHA IMIS database for the most recent 15-year period (1986 - 2001) showed that OSHA inspection files over that period contain a total of 11 full-shift hexavalent chromium personal exposures, and all of these exposures were collected prior to 1991. Two of these exposures were from the glass container industry; however, as stated in Section 21.1, hexavalent chromium is not used today in the glass container industry (GPI, 2002). Also, one of the worker's tasks are not described in the database, and the other worker is listed as a "mold maker,"

which is not believed to be used in this industry. Three of the exposures are from SIC Code 3231, Products of Purchased Glass. These establishments purchase glass rather than producing it themselves. One exposure is for a spray painter; this exposure will be included in Section 3, Painting. Two exposures are for platers; these exposures will be included in Section 1, Electroplating. One exposure for a mold cleaning grinder is believed to have been associated with producing glass for kitchen containers. Because hexavalent chromium is no longer used in glass containers, it is also projected that it is no longer used for kitchen containers. Hence, these nine exposures from the IMIS database are not considered in the exposure profile. Table 21-6 presents the remaining two full-shift IMIS full-shift exposures available for this industry.

Table 21-5. Total Chromium Monitoring Data Collected at Thomson Consumer Electronics (NIOSH, 1990)

Type of Sample	Job Category	Total Chromium Exposure ($\mu g/m^3$)[a]
Full-shift TWA[b]	Inspector/packer	9
		3
Full-shift TWA	Code dater	ND[c]
		ND
		ND
Area	Packing area	4
Area	Code dating area	ND

[a]$\mu g/m^3$ = Micrograms per cubic meter.

[b]TWA = Time-weighted average.

[c]ND = Not detected.

Table 21-6. IMIS Full-Shift Hexavalent Chromium Monitoring Data Collected at Glass-Producing Facilities (1986 - 2001)

SIC Code[a]	Date	Facility ID	Job Category	Full-Shift Hexavalent Chromium Exposure ($\mu g/m^3$)[b]
3229	10/86	A	Lab Assistant	1.3
	10/86	A	Lab Assistant	ND[c]

[a]SIC Codes: 3229 = Pressed and Blown Glass, N.E.C.

[b]$\mu g/m^3$ = Micrograms per cubic meter.

[c]ND = Not detected.

Table 21-7 presents full-shift worker exposures for hexavalent chromium in the colored glass production industry, based on the combined IMIS and NIOSH site visit full-shift occupational exposure data. In Table 21-7, each of the facilities sampled (IMIS and site visit data) is weighted equally. The percentages shown in Table 21-7 take into account equal weighting of the appropriate facilities included in the exposure data. The exposure profile in Table 21-8 applies the percentage of results in each range for job categories in Table 21-7 to the population of production workers potentially exposed to hexavalent chromium.

Table 21-7. Distribution of Full-Shift Personal Exposures (8-hour TWA) for Hexavalent Chromium in the Colored Glass Industry, Based on Combined IMIS and NIOSH Site Visit Data

Job Category	Total No. of Data Points	Distribution ($\mu g/m^3$)[a]							
		Below LOD[b]	LOD to <0.25	0.25 to <0.5	≥0.5 to <1.0	≥1.0 to <5.0	≥5.0 to <10.0	≥10.0 to <20.0	≥20.0
Lab Assistant	4	2 (50%)	1 (25%)	0 (0%)	0 (0%)	1 (25%)	0 (0%)	0 (0%)	0 (0%)
Batch Mixer	6	6 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Furnace Worker	1	1 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

[a]$\mu g/m^3$ = Micrograms per cubic meter.
[b]LOD = Limit of detection.

Table 21-8. Personal Exposure Profile in the Colored Glass Industry (Full-Shift TWA), Based on IMIS and NIOSH Site Visit Occupational Data[a]

Job Category	Total No. of Workers	Distribution ($\mu g/m^3$)[a]							
		Below LOD[b]	LOD to <0.25	0.25 to <0.5	≥0.5 to <1.0	≥1.0 to <5.0	≥5.0 to <10.0	≥10.0 to <20.0	≥20.0
Lab Assistant	6	3 (50%)	2 (25%)	0 (0%)	0 (0%)	2 (25%)	0 (0%)	0 (0%)	0 (0%)
Batch Mixer	43	43 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Furnace Worker	245	245 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	294	291 (98%)	2 (1%)	0 (0%)	0 (0%)	2 (1%)	0 (0%)	0 (0%)	0 (0%)

[a]Values may be affected by rounding.
[b]$\mu g/m^3$ = Micrograms per cubic meter.
[c]LOD = Limit of detection.

21.4 Technological Feasibility

21.4.1 Baseline Controls

Information regarding baseline controls was obtained during the site visit conducted by NIOSH to a colored glassware manufacturer (NIOSH, 2002). The site visited primarily uses local exhaust ventilation (LEV) to reduce worker exposure to hexavalent chromium. General dilution ventilation is also present, including systems specifically intended to provide air conditioning. It is estimated that all colored glassware manufacturing establishments have similar controls and work practices.

Hexavalent chromium pigments are weighed out and mixed with other ingredients necessary to produce colored glass prior to being fed into a furnace. In the furnace, the materials form a molten glass, and hexavalent chromium is converted to trivalent chromium. Glass blowers work with the molten glass after it is removed from the furnace to produce the final product. Job categories of workers who are exposed to hexavalent chromium in the colored glass industry are lab assistant, batch mixer, and furnace worker.

Lab Assistant

In addition to their laboratory quality assurance responsibilities, lab assistants weigh pigments for colored glass manufacturing. At the site visited by NIOSH (NIOSH, 2002), pigment crystals were scooped from a 8-gallon plastic container with a metal scoop and placed into 5- or 6-gallon plastic buckets on a scale underneath a small moveable canopy hood, which provides local ventilation. A 6-inch diameter flexible duct connected the canopy hood to an approximately 10-foot long hard duct that leads to the exhaust fan. The exhaust fan discharged to the dust collector. The hood had a face velocity of 645 fpm.

Batch Mixer

Pigment is received in 50-kg paper bags. At the site visited by NIOSH (NIOSH, 2002), batch mixers transferred pigment from the bags to 8-gallon plastic storage containers. Local exhaust ventilation was used during the transfer process. Batch mixers also assisted lab assistants while weighing pigments for the production of colored glassware.

At the site visited by NIOSH (NIOSH, 2002), the local exhaust ventilation for the batch weighing and mixing area included two large canopy hoods, a horseshoe-shaped slot-exhaust fixture, and a dust collector. Batch mixers transferred the raw materials, including pigments, into a hopper located on a scale in a pit on the floor. A 4-foot by 6-foot canopy hood located over the hopper

provided ventilation. In some cases, such as wheelbarrow additions, the hood was moved out of the way for adding materials, but the exhaust still operated. The average face velocity was 255 fpm.

The hopper was used to add materials to the mixer. A horseshoe-shaped exterior hood, with a continuous 2-inch slot on the inside face, encircled the small chute on the top of the mixer. The average face velocity was 550 fpm. A second canopy hood was located at the bottom of the mixer. The 6-foot by 5-foot hood controlled dust as material was dumped from the mixer into a receiving hopper.

The dust collector was a "self-cleaning" baghouse system. Bags were changed three times per year. The system was automatically designed to shake down. When the exhaust fan was stopped, a 1/4-second blast of air, from plant air and a self-actuating solenoid, shook and "back flushed" dust from the bags. Also, each weekend, the bags were manipulated by hand to remove encrusted dust, which caked at the top of the bags.

Furnace Worker

There is no local exhaust ventilation available for this worker. There is, however, building ventilation which provides substantial rates of general dilution airflow, and this airflow has an influence on airborne contaminants in the breathing zone of the furnace worker.

21.4.2 Additional Controls

21.4.2.1 Additional Controls to Achieve a 20 μg/m³ 8-Hour TWA Alternative PEL

Based on current full-shift hexavalent chromium median exposures, no additional controls will be required to achieve 8-hour TWA exposures of less than 20 $\mu g/m^3$ for any of the three job categories of workers involved in colored glass production (lab assistant, batch mixer, and furnace worker).

21.4.2.2 Additional Controls to Achieve a 10 μg/m³ 8-Hour TWA Alternative PEL

Based on current full-shift hexavalent chromium median exposures, no additional controls will be required to achieve 8-hour TWA exposures of less than 10 $\mu g/m^3$ for any of the three job categories of workers involved in colored glass production (lab assistant, batch mixer, and furnace worker).

21.4.2.3 Additional Controls to Achieve a 5 μg/m³ 8-Hour TWA Alternative PEL

Based on current full-shift hexavalent chromium median exposures, no additional controls will be required to achieve 8-hour TWA exposures of less than 5 μg/m³ for any of the three job categories of workers involved in colored glass production (lab assistant, batch mixer, and furnace worker).

21.4.2.4 Additional Controls to Achieve a 1 μg/m³ 8-hour TWA Alternative PEL

Based on current full-shift hexavalent chromium median exposures, no additional controls will be required to achieve 8-hour TWA exposures of less than 1 μg/m³ for two of the three job categories of workers involved in colored glass production (batch mixer and furnace worker). Additional controls will be needed for the remaining job category, lab assistants.

Lab Assistants

Based on full-shift TWA hexavalent chromium exposures documented with baseline controls, additional controls will be necessary at a few facilities to achieve 8-hour TWA exposures of less than 1 μg/m³ for lab assistants. The majority of documented full-shift hexavalent chromium exposures for lab assistants (4 of 5 full-shift personal hexavalent chromium exposures) are well below 1 μg/m³. Work controls documented in the NIOSH site visit report (NIOSH, 2002) show full-shift hexavalent chromium exposures for lab assistants below the detection limit (<0.02 μg/m³) with associated engineering controls (i.e., a moveable canopy hood connected to a dust collector). This demonstrates that work controls similar to those used at the site visited are capable of reducing full-shift hexavalent chromium exposures to below 1 μg/m³ for lab assistants.

21.4.2.5 Additional Controls to Achieve a 0.5 μg/m³ 8-Hour TWA Alternative PEL

Based on current full-shift hexavalent chromium median exposures, no additional controls will be required to achieve 8-hour TWA exposures of less than 0.5 μg/m³ for two of the three job categories of workers involved in colored glass production (batch mixer and furnace worker). Additional controls will be needed for the remaining job category, lab assistants. The additional controls addressed under the 1 μg/m³ alternative PEL are also estimated to be capable of meeting the 0.5 μg/m³ alternative PEL for lab assistants.

21.4.2.6 Additional Controls to Achieve a 0.25 μg/m³ 8-Hour TWA Alternative PEL

Based on current full-shift hexavalent chromium median exposures, no additional controls will be required to achieve 8-hour TWA exposures of less than 0.25 μg/m³ for two of the three job categories of workers involved in colored glass production (batch mixer and furnace worker).

Additional controls will be needed for the remaining job category, lab assistants. The additional controls addressed under the 1 $\mu g/m^3$ alternative PEL are also estimated to be capable of meeting the 0.25 $\mu g/m^3$ alternative PEL for lab assistants.

21.4.3 Substitutes for Chromate-Containing Pigments in Colored Glass

Chromium green is a staple ingredient for this industry. The facility visited during the site visit (NIOSH, 2002) did not foresee a possibility of eliminating its use, as they have several product lines, even some military specifications, that require its use.

21.5 References

Centaur Associates, Inc. Technological and Economic Analysis of Regulating Occupational Exposure to Chromium. Draft Final Report. Prepared under contract to the Occupational Safety and Health Administration. June 1981.

Glass Packaging Institute. Personal communication with IT Corporation on November 18, 2002.

Kirk-Othmer Encyclopedia of Chemical Technology, Fourth Edition, v.12. John Wiley and Sons. New York, NY, pp. 555-624, 1994.

National Institute for Occupational Safety and Health (NIOSH). October 1990. Health Hazard Evaluation Report HETA 89-244-2068, Thomson Consumer Electronics, Inc., Circleville, Ohio.

National Institute for Occupational Safety and Health (NIOSH). November 2002. Site 6 - A Colored-Glassware Manufacturing Facility.

Roskill Information Services Ltd. The Economics of Chromium 1993. Eighth Edition. 1993.

U.S. Census Bureau, 2000 County Business Patterns.

U.S. Census Bureau, 1997 Economic Census, Other Pressed and Blown Glass and Glassware Manufacturing. November 1999.

U.S. Census Bureau, Statistics of U.S. Businesses: 1999: Manufacturing.